REMARKS

Claims 12-27 are now pending in this application. Claims 1-11 are rejected. Claims 1-11 are cancelled herein. New claims 12-27 are added and intended to replace prior claims by expressing the invention in alternative wording to broaden language as deemed appropriate and to address matters of form unrelated to substantive patentability issues.

PARAGRAPH FOR SUBSTITUTE SPECIFICATION AND ABSTRACT

Applicant submits herewith a substitute specification and abstract wherein amendments are effected to place the text thereof into proper English in accordance with 37 CFR 1.125(c). Also accompanying this amendment is a marked specification which is a reproduction of the original specification and abstract with markings indicating the amendments effected in the substitute specification in accordance with MPEP §608.01(q) and 37 CFR 1.125(b). The amendments indicated in the marked specification reflect new amendments and the prior amendments made by preliminary amendments in order to consolidate a amendments to date. No new matter is added. Entry of the substitute specification and abstract is respectfully requested.

CLAIM REJECTIONS UNDER 35 U.S.C. § 112, SECOND PARAGRAPH

Claims 1-11 are rejected as indefinite under 35 U.S.C. § 112, second paragraph, for failing to particularly point out and distinctly claim the subject matter of the invention as a result of informalities stated in the Office Action. The claims are now cancelled rendering said rejection moot.

Claims 1-11 are replaced by claims 12-27 which reflect similar subject matter but are structured in a manner better conforming to U.S. claiming practice standards. The claims are worded to remove or correct the informalities noted in the Office Action. The Office Action questions the meaning of "peel grinding" used in the claims. This term is a term of art which is described in the last page of the attached article, "EMO 99: Show Report," Machine Shop Guide Web Archive, July/August 1999.

In view of the above, allowance of new claims 12-27 is earnestly requested.

CLAIM REJECTIONS UNDER 35 U.S.C. §103(a)

Claims 1-11 are variously rejected as obvious over the Gruber '830 reference, the EP '446 reference, and the GB '457 reference under 35 U.S.C. §103(a). Claims 1-11 are now cancelled rendering their rejection moot. However, insofar as the subject matter of new claims 12-27 reflects that of the cancelled claims and in the event the Examiner considers asserting the present rejection against the new claims or making the next Office Action final, applicants submit the following remarks.

It is believed that a brief explanation of the invention is warranted in order to clarify the distinctions of the present apparatus and method claims. According to page 1, first paragraph, of the original description the present invention is directed to grinding of a specific workpiece having a substantially conical shape with a substantially straight contour. Such a workpiece is shown in figure 3 of the application documents.

On page 1, paragraph 3 to page 2, paragraph 1 of the original description it is stated in the prior art the workpiece was only machined by the angular infeed grinding method, by grinding wheels having a conical contour on a corundum basis. The disadvantages connected therewith are reflected in the specification by the following text:

> The known method has a number of disadvantages. First, it requires grinding wheels with a conical shape or with a highly graduated diameter, which are difficult to manufacture and dress. In such grinding wheels with circumferential regions of very different diameters, the circumferential speeds of the regions to be ground are also different. This means that the critical cutting speed at the grinding location must be different and therefore cannot be optimal over all. The result of this [[is]] <u>are</u> regions of varying roughness, which has a negative effect on the active surface. Finally, there are also problems involving cooling by means of the conventional emulsions and grinding oils. That is, during angular infeed grinding a narrowing wedge occurs at the grinding location, and coolant/lubricant cannot be fed to it optimally. The result is thus uneven cooling of the grinding location. All of these difficulties can be traced back to the fact that the aforesaid known method has in the past been performed with corundum grinding wheels, which have a significantly shorter service life and must be dressed more frequently

than CBN grinding wheels, which have since come into wide use.

Specification, pages 1 and 2. The Gruber reference cited in the Office Action applies the angular infeed grinding method referred to in the background section of the present specification. The wheel head 14 in Gruber is obviously horizontally (related to the drawing according to figure 1) moved towards the headstock 11 with the workpiece 13 so as to insert the "V" of the grinding wheel into the workpiece 13. Such a "V" shape dictates that the conical "V" shaped grinding wheel be moved horizontally (in its radial direction) in order to properly grind the workpiece.

In contrast, the present method claim 12 and apparatus claim 19 provide that a substantially flat surface of the workpiece is to be ground by a grinding wheel that has an outer surface with a "substantially straight line contour extending in an axial direction and parallel to an axis of said first grinding wheel" and that it is positioned "with said axis of said first grinding wheel aligned parallel to said substantially conical surface and said outer grinding wheel surface aligned along a direction of said workpiece axis with said substantially conical surface of said workpiece in said chucked state." Additionally, the claim recites "an axial length of said outer grinding wheel surface of said first grinding wheel extending over an entirety of said substantially conical surface" of the surface to be ground.

The above noted features contrast with the arrangement of the Gruber reference according to figure A of the attached EXAMPLE FIGURES. Figure A

represents the arrangement of Fig. 1 of the Gruber reference wherein the grinding wheel comprises a cone-like contour and that the rotational axis of the wheelhead and the workpiece are arranged in an oblique way with regard to each other; thereby the infeed movement is effected by the wheelhead, perpendicularly to the direction of the axis of the grinding wheel. The disadvantages of the angular infeed grinding method are discussed in the above reproduced portion of the specification.

If the disadvantage of the cone-like grinding wheel is to be avoided and a cylindrical grinding wheel is to be used, the axis of the wheel head has to be arranged still further obliquely, as it is represented in figure B of the attached EXAMPLE FIGURES. This arrangement is not shown or suggested by the Gruber reference. The infeed of the wheel head in an oblique direction always requires a more difficult construction of the machine if a precise grinding result is to be achieved.

The presently claimed invention avoids the above difficulty. Since the conical body of the workpiece is only pivoted little, the arrangement according to figure B is further modified in the present invention such that the first grinding wheel and the workpiece are relatively displaced in the direction of the workpiece axis.

Claim 13 further recites that feature that the grinding "is effected by moving said workpiece in said chucked state in a direction of said workpiece axis into said first grinding wheel" an claim 22 recites a corresponding feature of the apparatus. The feature of the claims allows the pivoting grind headstock to remain stationary during grinding. This arrangement is represented in figure C of the attached

EXAMPLE FIGURES.

It is respectfully submitted that the combination of the features of claim 12 provide:

-substantially cylindrical grinding wheel and an arrangement of the rotational axes of the workpiece and the grinding wheel in an oblique way with regard to each other by virtue of the substantially conical configuration of the workpiece; and

- relative infeed of the grinding headstock and the workpiece in the direction of the rotational axis of the workpiece the grinding wheel covers the active surface 24 of the flat truncated cone by its axial width,

which present a combination which is not suggest by the applied references. Additionally, the feature that - the wheel head is stationary during grinding operation - presented by claim 13 is still further removed from the teachings of the cited references.

Furthermore, the feature of claim 12 that the first grinding wheel covers by means of its axial width the substantially flat truncated cone, meaning the active surface 24 to be ground, additionally distances the claimed combinations from the cited references and allows the substantially conical surface to be completely ground by virtue of the width of the outer grinding wheel and its alignment in the direction

of the workpiece axis with the substantially conical surface. A misalignment in this respect is represented in figure D of the attached sketches.

Pivoting of the grinding headstock with the first and the second grinding wheel is necessary in order for the workpiece to be ground in one and the same chucking. These operations are reflected in method claim 12. Because the grinding headstock can be pivoted to position the first and second grinding wheels into proper grinding alignment with the workpiece in the same claimed chucked state, it is no longer necessary to unchuck the workpiece in order to machine both the substantially conical surface of the active surface and the central bore. Furthermore, as recited in claim 12, the infeed movement can be accomplished by relative motion of the workpiece and the first grinding wheel in the longitudinal direction of the workpiece axis. Such movement can be carried out with high accuracy and speed. Claims 13 and 22 provide for the relative movement being effect by movement of the first grinding wheel.

With regard to the applied references, a review of the operation and teachings therefore should suffice to make evident the deficiencies of the references in providing the suggestions to arrive at the present invention. The '466 reference teaches a device with a wheelhead 14 carrying first and second wheels Ga and Gb, the wheel Ga being conical and used for cylindrical grinding of the exterior of a cylindrical workpiece and the wheel Gb being rotatably positioned about the axis θ2 so as to effect internal grinding of a bore as shown in Fig. 7f. The reference

fails to teach the grinding of a conical workpiece by relative advancement of the workpiece and grinding wheel along a workpiece axis. The Examiner turns to the Gruber reference for teaching the grinding of a conical workpiece and theorizes it would be obvious to combine the references to arrive at the present device.

There is very little connection to the subject matter of the present application and the '446 reference except that a grinding spindle head carries two grinding spindles with the grinding wheels Ga and Gb. By pivoting the grinding spindle head the two grinding wheels can be brought into working position. However, according to the '446 reference only cylindrical workpieces are machined which are chucked on both sides. The arrangement does not suggest the presently claimed arrangement because of the different functioning arrangement of the device. Figures 1 and 2 show an external cylindrical grinding of a cylindrical workpiece W comprising a cylindrical portion Wa. This workpiece W is chucked on both sides and does by no means have any longitudinal bore nor does it comprise any frontal end surface in the shape of a flat truncated cone surface.

Contrary thereto, in figures 7a to 7f only the internal cylindrical grinding with a small grinding wheel Gb is represented and described. The workpiece W1 representing an example therefor has the shape of a short piece of a pipe which naturally has to be chucked on one side and does not have any frontal end surface as effective surface in the shape of a flat truncated cone surface. Nothing gives any suggestion that the two embodiments according to figures 1 and 2 on the one hand

and according to the figures 7a to 7f on the other hand can be combined with each other. Furthermore, the reference fails to provide any suggestion of the arrangements presented being capable of effectively grinding a substantially conical surface.

Furthermore, as shown in figure 8 the grinding wheel Gc cited in the Office Action is shown having cone like grinding surfaces, in contrast with the claimed outer grinding wheel surface which is parallel to the first grinding wheel axis, and is shown grinding only the cylindrical workpiece W already shown from figure 1 being ground. The '466 reference points at the fact that the reference position of the workpiece with regard to the grinding wheel is to be made independent of inaccuracies which under certain circumstances could result from the chucking of the workpiece. It is essential to the method according to '466 reference that the reference surface W, is to serve as reference surface for the first grinding process. Accordingly, this procedure does not have any relation to the method and device according to the present application since it bears no relation to grinding the claimed substantially conical surface.

The disclosure of the '466 reference read in context at, column 5, lines 23 to 32, relates only to longitudinal grinding. Frontal end faces in the shape of a substantially flat truncated cone surface can only occur in surfaces which substantially run transversely to the longitudinal axis of the workpiece. However, the "446 reference fails to make any mention of such surfaces. Thus, the proposal in the Office Action to combine the '446 reference with the Gruber reference cannot be

based on teachings of the respective references in view of the '466 reference teachings, and hence can only stem from the disclosure of the present invention. In this regard it is called to the Examiner's attention that, the '446 reference does not hint that device surfaces running transversely to the longitudinal axis of the workpiece W could be ground with the large grinding wheel Ga in a perpendicular grinding process, i.e., with the grinding wheel axis parallel to the surface running transverse to the workpiece axis. As such, the presently claimed feature of the application, namely the perpendicular grinding of a truncated cone surface area is not at all mentioned in the '446 reference.

The cited Gruber reference which is combined with the '446 reference is an example of an arrangement using cone-like grinding wheels which is obviated by the presently claimed invention. The Gruber reference only demonstrates the common grinding of a cone-like workpiece according to the method of angular infeed grinding. By using the angular infeed grinding method the grinding wheel is infed perpendicularly to its rotational axis onto the conical workpiece corresponding to the text in Gruber according to column 3, lines 21 to 25. It is the grinding spindle that is moved perpendicular to its axis. The material that is ground by respective positions on the grinding wheel differs from the material ground by the respective positions of the first grinding wheel of the presently claimed invention because in the claimed invention the relative displacement is in the direction of the workpiece axis. This is because he advancement of the grinding wheel through the material of the

workpiece is in a different direction. Accordingly, interchange of movement does not produce an equivalent result.

In summary, the '446 reference does not deal with a grinding of workpieces having the shape of a substantially flat truncated cone. The Gruber reference describes grinding of conical workpieces only by means of a conical grinding wheel according to the method of the angular infeed grinding in which movement is perpendicular to the axis of the grinding wheel. Thus, the combination of the '466 reference and the Gruber reference cannot lead one to the claimed invention because of the lack of suggestion in view of the differing functional arrangements of the references and also because none of the references teaches the feature of grinding the substantially conical surface using a grinding wheel with its axis arranged parallel to the substantially conical surface and relative movement effect in the direction of the workpiece axis.

The GB 457 reference is merely cited for the use of three grinding wheels on a pivotal wheelhead 18 and its mention of conical grinding. The combination of this cited reference with the Gruber reference ignores all technical facts, does not lead to the invention and is only possible when knowing the present invention. The '457 reference of the year 1912 among others describes a grinding machine with a turret unit by means of which different grinding wheels are to be brought into contact to a workpiece. The object of this application is the transferral of the driving belts onto the pulleys of the single grinding wheels. The belt of this machine, however, can only

be transferred onto the respective driving pulleys in the position as represented in figure 5. In this position the rotational axis of the respective grinding wheels runs parallel to the longitudinal axis of the workpiece and the workpiece holder 3, as represented in figure 5. The belt drive imposes large restrictions to the adjustability of the turret. It is absolutely impossible to bring into position one of the grinding wheels by means of which it could, by means of its rotating circumferential surface, machine a surface running transversely to the longitudinal axis of the workpiece in a perpendicular grinding method.

In all figures of the '457 reference the workpieces are shown having only cylindrical contours. Regarding the grinding of conical parts, only an isolated remark can be found on page 2, lines 22 to 23. According to this remark the workpiece holder 14 is to be obliquely arranged for grinding conical parts. In connection with the other statements and descriptions and representations of the '457 reference, the person skilled in the art can only derive at the statement that conical portions of a workpiece can only be ground by longitudinal grinding. Hints to grinding of flat conical areas in a perpendicular grinding method are by no means presented in the reference.

Thus, it is respectfully submitted that the new presented claims are not obvious in view of the cited references for the reasons stated above. Favorable consideration of the rejections of the new claims and their allowance are respectfully requested.

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REQUEST FOR EXTENSION OF TIME

Applicant respectfully requests a three month extension of time for responding to the Office Action. **The fee of $1020.00 for the extension is provided for in the charge authorization presented in the PTO Form 2038, Credit Card Payment form, provided herewith.**

If there is any discrepancy between the fee(s) due and the fee payment authorized in the Credit Card Payment Form PTO-2038 or the Form PTO-2038 is missing or fee payment via the Form PTO-2038 cannot be processed, the USPTO is hereby authorized to charge any fee(s) or fee(s) deficiency or credit any excess payment to Deposit Account No. 10-1250.

In light of the foregoing, the application is now believed to be in proper form for allowance of all claims and notice to that effect is earnestly solicited.

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Respectfully submitted,
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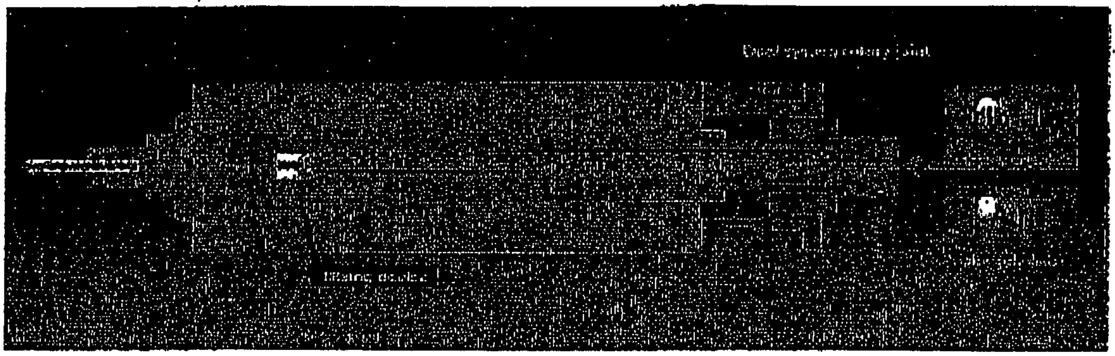
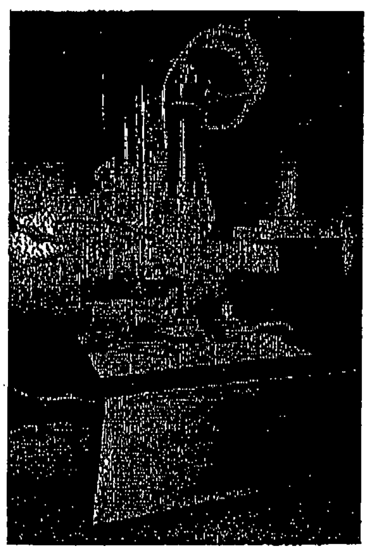
enc: Form PTO-2038; EXAMPLE FIGURES Figs. A-D; Substitute Specification; copy of "EMO 99: Show Report," Machine Shop Guide Web Archive, July/August 1999; and Marked reproduction of original specification.



In a Horkos machining center spindle, separately supplied minute amounts of cutting fluid and air travel down the spindle and are mixed inside the spindle just in front of the tool shank

The dry chips and machining dust collect in a hopper outside the machine.

Feeding bar stock to a machining center is one concept for volume small-parts machining shown at EMO. A Willemin (distributed by Hansco Technologies in the USA) 418B compact 5-axis machining center was equipped with an LNS Quick-Load Servo magazine short-bar feeder and a Lehmann rotary table. It was set up to take 32-mm bar, but could handle bar to 60 mm. Internal grippers held cut-off parts so the back end could be machined.



Kern micromilling machine

On the Chiron FZ 08 model, machining from bar stock is similarly facilitated with an NC rotary table with 80 rpm face plate speed, a special collet chuck device, and pneumatic bar feeding equipment.

For the special job of drilling deep holes in automotive castings without indexing the part 180°, Heckert's new CWK 630D HMC can take drills to 800 mm length in its tool storage and change them automatically. With this capability, long hole runs can be drilled from one side only with increased precision and reduced cycle times. Heckert is now part of the Starrag-Heckert group.

Turning machine technology

Under turning we take an overview of EMO debuts in turn/mill, bar automatics, VTLs, and more.

Turn/mill centers continue to add capability so that ever more complex part geometries can be machined complete. The integrated milling modules have the capability of a small machining center built into the "lathe," with multiple axes of motion, a toolchanger, and increasing larger tool capacities. On most turn/mill machines, machining can take place simultaneously on the main and counterspindle. Such "lathes" are expensive relative to ordinary CNC lathes but the amount of automation they possess allows parts to be produced at markedly lower cost, making them a competitive option.

Gildemeister (DMG America) introduced the MF twin 300 TC, replacing the front turret head of their MF twin 300 with a milling/drilling spindle. With two coaxially arranged turning spindles, a 12-station turret with stationary and driven tools, and a milling head with Y and B axes, the machine can perform 6-sided machining on complex components from bar or slugs in one cycle. The milling spindle drive is 30 kW; maximum number of tools is 80.

Index Werke's Ratioline G300 Flex has added a machining center package onto its basic modular construction G300 model, possessing up to a 120-tool magazine serving the upper tool carrier. A lower tool carrier/turret may carry 12 or 24 tools, giving the machine a maximum tool capacity of 148 tools. The upper tool carrier has Y and B axes and can carry out an almost unlimited variety of machining operations.

Mazak has developed its multifunction Integrex turn/mill center into a family with at least five members, four of which were shown in the Mazak booth. The Mazak booth at EMO, incidentally, was often as packed as a New York subway train in rush hour. The Integrexes all feature C, Y, and B axes and a second spindle. The design now has gone to a single tool "turret" with rapid toolchange times. All now feature the 64-bit Fusion 640 control.

The 200SY and the 400Y are new models. The Integrex 200SY has two spindles with automatic work transfer from the first spindle to the second to complete the work. Its spindle for rotational tools has a 10-hp, 6000-rpm drive which may be employed to work on the first or second work spindles. Max machining envelope is 500 mm diameter x 1018 mm length. Y-axis movement is 5.5-in. B-axis travel is 225°. The tool magazine holds 20 tools but options are available with up to 80. The Integrex 400Y has a max machining diameter of 600 mm and offers a 20-hp 6000-rpm spindle. The turret incorporates a 20-hp 6000-rpm spindle for rotational tools. Other Integrexes in the booth were the 50Y 2500U and the 200Y.

Okuma's new MacTurn 30-W featured a 3800-rpm main spindle, 4500-rpm subspindle and a 6000-rpm milling spindle. With Y and B axes, including 0.001° B-axis indexing to allow for angular milling, the machine has great versatility. The ATC can hold 20 (standard), 40, or 80 tools.

Hitachi Seiki's HiCell has been upgraded to the Super HiCell with 7.5 kW driven tool capability with 8000- or, optionally, 12,000-rpm. The Super HiCell can have 20- or 40-tool magazines. A variety of second-spindle options and chuck sizes are available. The 3-axis turret

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head has travels of 600 mm in X, 1000 mm in Z, and ±60 mm either side of centerline for the Y-axis cross-feed.

Automatics and other lathes

If you believe that more is more, then you'd want to look at the MultiLine MS32 CNC "6-spindle" automatic from Index. This 32-mm CNC bar machine comes in three versions, with the most complex being the "G" option with two complete spindle drums: six first spindles and six second operation spindles facing them, for those high-volume jobs that require extensive backworking. The individually driven motor spindles ensure optimum cutting speeds. With a building-block concept, you order the type of tool carriers needed for your work; not every station needs to be 2-axis contour controlled. This advanced and expensive machine is programmed one spindle position at a time, with synchronization taken care of by the Index software.

Index CNC multi-spindle automatic with six main and six back-working spindles

At EMO, Tornos added two machines to its successful DECO line, first introduced in 1996. The DECO line has offered the speed of cam machines with the faster setup and better precision of CNC machines, thus reviving the fortunes of Tornos. The six-spindle, 18-axis Multi-DECO provides bar capacity to 20 mm, which is a smaller model than the original Multi-DECO 26 mm. Added to the single-spindle series is the 13 mm DECO 2000. Three of its back-working tools are mounted on an independent slide, permitting simultaneous turning and drilling. All cross drilling/milling/turning tools can be driven or stationery. Tornos updated its TB-DECO software, speeding calculation time by two to four times.

In single-spindle automatics, new models were shown by Gildemeister and Traub/Index, while new Swiss-style CNCs were shown by Citizen Cincom and Star. The Gildemeister Ergomat TDA-26 and its larger brothers are digital CNC versions of traditional cam-controlled automatics. The Citzen Cincom M12 featured a Mitsubishi flat-panel control, one of many such flat-panel controls seen throughout EMO. The control allowed up to three tools to be cutting simultaneously. The Star SR-16/20 can carry up to 20 tools, including four back-working and four cross-working tools, and features faster slide positioning at 20 m/min rapids. Index showed the Traub TNL 26 sliding-headstock automatic, which can put up to four tools in the work simultaneously. This machine is nearly identical in design to its cousin, the fixed-headstock TNK 28/36, which is a successor to cam-driven single-spindle automatics.

Among high-precision single-spindle CNC turning machines were the Spinner (Monarch) UP 42 and UP 65 lathes. The bases are composed of precision-machined cast iron with 6 tons of polymer concrete to absorb vibrations. Spinner guarantees for their ultra-precision machines roundness and positioning repeatability below 1 micron. Linear scales in X/Z and resolution of 0.1 micron are standard. These machines are sometimes sought for finish hard-turning applications, as are the Slantbed Mikroturns 100 and 50 CNC from Hembrug, a Dutch machine builder. The Mikroturns are ultra-precision lathes with oil-hydrostatic slides with repeatability of ±0.1 micron and a hydrostatic main spindle with runout less than 0.1 micron. CNC resolution is 0.01 micron. A natural granite base absorbs vibration. The new, compact model 50 will chuck workpieces to 120 mm diameter, while the model 100 will chuck work to 310 mm.

Hardinge demonstrated the gang-tooled Conquest GT27SP Autoload with an out-of-the-box gantry type parts loading/unloading system. It is designed so that the moving gantry automation does not impact part accuracy. (Look to next month's issue for more on this machine.) Takisawa has upgraded its famous CNC Piston Turning machine. The new model TPS-5000 now sports a back spindle and a second turret to finish additional turning operations.

Weiler Machine Tools showed a wide range of its lathes with automated cycles. This type of lathe, which first appeared a decade ago, is ideal for small lots and prototype work. The Weiler E-series lathes, with swing diameters ranging from 3 to 47 in., offer 13 automated cycles without requiring CNC training. Some of the cycles are for recessing, threading, thread undercutting, and grinding undercutting. The machines feature graphically-assisted profile programming for even the most complex profiles. Points of intersection are automatically calculated.

In vertical turning, the trend toward inverted verticals, with the workhandling automation managed by the spindle itself, continues. Builders introducing new or modified entries in this field included EMAG, Hitachi Seiki, Index, and Weisser. Trends here are toward adding more tooling, as Index has done by adding a second turret, extending the product line to larger sizes, as Hitachi Seiki has done, or developing combined operations, as EMAG and Weisser have done.

In so-called "conventional," as opposed to inverted vertical turning, Pietro Carnaghi (IMTA) has developed a new machine that is anything but conventional. The large 40 kW ATL machine turns work to 1200 mm by 750 mm high and comes with a toolchanger and a two-pallet system, like a two-pallet table on an HMC. Construction is fabricated rather than cast and, like the Dixi Jig Center 350, rests on three points, requiring no special foundation. It employs hydrostatic guideways. Axis rapid speed is 40 m/min.

New production grinders at EMO

The new production grinders we saw at EMO can be divided into two categories: universal or general cylindrical grinders, and special purpose grinders.

Kellenberger, a Hardinge company, showed the Kel-Vision compact universal CNC cylindrical grinder with 17-in. grinding length for external, internal, and face grinding. The X and Z axes are underneath the wheelhead, while the table is stationary, for outstanding repeatability. The swiveling wheelhead permits OD and ID grinding on the same machine. An optional RS-type wheelhead allows OD and face grinding with angular wheel approach. The grinding wheel drive motor is water-cooled and the external grinding spindle has hydrodynamic bearings, yield-

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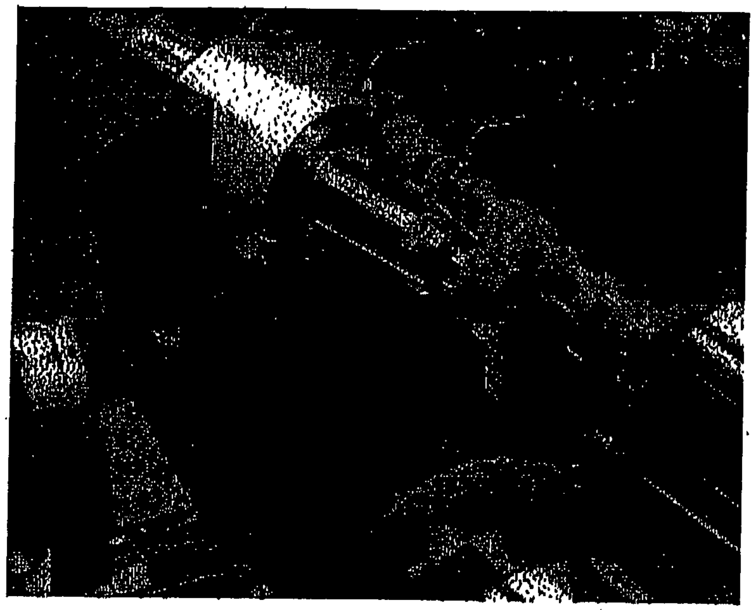
ing high thermal stability.

Voumard unveiled its 120 CNC production grinder for IDs, ODs, and faces. It is designed for small to medium sized automotive parts such as gears or components for fuel injection systems, which may have an ID and an OD ground simultaneously. It can be equipped with an optional turret with two internal grinding spindles. Presented without a loader at EMO, the machine may be equipped with a variety of loading devices. Maximum external workpiece size is 160 x 80 mm with manual loading or 120 x 80 mm with automatic loading.

Okuma also affered a mid-size grinder for mass production, the GA-26T OD grinder with angular wheelhead. It has a between-centers capacity of 350 mm with a max grinding diameter of 200 mm. Rapid traverse is 20 m/min. For shorter turnaround, the dressing cycle takes place during loading. Toyoda demonstrated the more general purpose GU4 OD/ID CNC universal grinder. The manually swiveled wheelhead can carry a straight OD or an angular OD wheel and an ID wheel. Distance between centers is 100 or 150 mm.



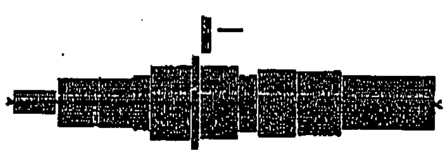
Kopp 5-axis grinding of racing car camshafts with conical CBN wheel

The Index Flex G300 turn/mill machine: is it as far as turn/mill can go?

Jones & Shipman launched their Ultramat X microprocessor-controlled universal cylindrical grinder with 300 x 650 mm grinding capacity. Programming is by touch-key membrane panels, with rapid setup for dress and grind cycles. Tacchella Machine (IMTA) showed a small Elektra 513 and the mid-size Elektra 1018 microprocessor-controlled universal cylindrical grinders. These come in both CNC and microprocessor-controlled (MPC) versions. The machines are designed with small footprints and are meant to be easy-to-operate in either MPC or CNC versions. Workpiece capacity of the 7.5-kW 1018 is 350 x 1000 mm. Perhaps not as well known in the USA as some of the other grinder names, Tacchella is a respected name in grinding in Europe.

Among builders of special-purpose grinders, Kopp has long had a fine reputation as an innovative firm. At EMO, Kopp (represented in the USA by GTI) showed a model of the technology on their SN 800 machine for 5-axis grinding of camshafts for racing cars with CBN wheels. To grind camshafts with five axes is new. Three axes are rotary and two are linear. The small conic wheel puts a small concave radius form (18 mm minimum) in the cams of the camshafts, giving the racing engines an extra boost. The machine is equipped with three grinding spindles, a rough grinding spindle, a finish grinding spindle, and the high frequency spindle for the conical wheel.

Grinding firms of the Schleifring Group (United Grinding Technologies) had new introductions. The Mikrosa Kronos "favorit" centerless grinder, with grinding wheel size of 610 mm diameter by 250 mm, offers high stiffness and highly dynamic drives to achieve greater cutting volume and lower material removal costs. Its 4 CNC axes, Granitan machine bed, and compact design contribute to its ability to support high-speed grinding with CBN wheels. Schaudt's ZX11 HSP "Peel Grinding" machine is designed to grind transmission and similar shafts in low-to-mid volumes. Peel grinding, more common in Europe than in the USA, is plunging in to perhaps a depth of 0.015 to 0.020 in. with a thin CBN wheel and then traverse grinding the length of the diameter. The technology has proven its advantage in smaller lots where you want to minimize wheelchange times. Max grinding length is 500 mm; grinding diameter is 200 mm. In-process rough and finish grinding is supported. The CR 41 CBN CNC Crankshaft Grinding Machine, also from Schaudt, is designed for continuous path-controlled grinding of pins on today's smaller crankshafts and compressor shafts. In this method, the crankshaft rotates concentrically around the main bearing middle axis. Only CBN wheels are used and all the pin bearing seats are ground accurately in one setup. There is no complicated eccentric chucking. Pin bearing seat roundness of <2 microns is achieved. Hydrostatic guideways provide high damping and high stiffness. The grinding spindle and the workhead motor are liquid cooled. Grind length is 700 mm.



Schaudt's peel grinding concept

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METHOD AND APPARATUS FOR EXTERIOR AND INTERIOR GRINDING OF A ROTATIONALLY SYMMETRICAL MACHINE PART PROVIDED WITH A LONGITUDINAL BORE

<u>Background of the Invention</u>

The invention relates to a method for grinding a rotationally symmetrical machine part provided with a longitudinal bore, [[the]] <u>a</u> one end-face surface of which is embodied as an active surface in the form in particular of a flat truncated cone with a cross-section with a straight or curved contour~~, in accordance with the preamble to claim 1~~.

The machine parts to be ground with this method are present for instance in transmissions with continuously variable gears, as are needed in motor vehicles. Two machine parts oppose one another with active surfaces facing one another. The active surfaces thus form an annular space with a nearly wedge-shaped cross-section in which a tension member<u>,</u> such as for instance a chain or a belt<u>,</u> moves in and out between different radii depending on [[the]] <u>a</u> distance from the active surfaces. Since such a transmission must work very precisely and transmit large torques, high demands are placed on the dimensional stability and surface quality of the machine parts. This also applies to the associated grinding procedures, in particular when grinding the active surface.

In accordance with the prior art known from commercial practice, the method cited in the foregoing has been performed in single operations, that is, in a plurality of clampings. The active surface is ground by means of corundum grinding wheels using the angular infeed grinding method. For interior cylindrical

grinding of [[the]] a longitudinal bore located on the machine part, the machine part must then be clamped in another machine, where the internal cylindrical grinding of the bore wall can occur using an appropriate small grinding wheel.

The known method has a number of disadvantages. First, it requires grinding wheels with a conical shape or with a highly graduated diameter, which are difficult to manufacture and dress. In such grinding wheels with circumferential regions of very different diameters, the circumferential speeds of the regions to be ground are also different. This means that the critical cutting speed at the grinding location must be different and therefore cannot be optimal over all. The result of this [[is]] are regions of varying roughness, which has a negative effect on the active surface. Finally, there are also problems involving cooling by means of the conventional emulsions and grinding oils. That is, during angular infeed grinding a narrowing wedge occurs at the grinding location, and coolant/lubricant cannot be fed to it optimally. The result is thus uneven cooling of the grinding location. All of these difficulties can be traced back to the fact that the aforesaid known method has in the past been performed with corundum grinding wheels, which have a significantly shorter service life and must be dressed more frequently than CBN grinding wheels, which have since come into wide use.

DD 143 700 concerns an apparatus for grinding tungsten plates that are used for instance as rotating electrodes in x-ray tubes. According to the drawing, such a tungsten plate has the contour of a truncated cone in which the incline of the surface line is approximately 30° relative to the base. In this known apparatus, the tungsten plate is clamped in a workpiece holder that is pivotable about an axis perpendicular to the apparatus frame. Situated opposing the

workpiece holder is a longitudinal support that is displaceable in the horizontal plane. Arranged on the longitudinal support is a compound slide rest that carries a grinding spindle for driving a small cylindrical grinding wheel that acts for internal grinding of a bore in the tungsten plate. Separated from this compound slide rest, the longitudinal support furthermore carries a rigid electrogrinding spindle for driving a conical grinding wheel. One end face and the cone envelope-shape region of the tungsten plate [[are]] is to be ground with the conical grinding wheel. For this, the conical grinding wheel and the tungsten plate must be brought into the correct position relative to one another by pivoting the workpiece holder, displacing the longitudinal support, and using manually actuated advancing controls.

Nothing other than angled grinding in the region of the cone envelope can be ~~taken from~~ done by DD 143 700. The known apparatus, which must in part be operated manually, is difficult to operate and requires some skill.

Known from EP 1 022 091 A2 is a tool machine for grinding workpieces in which two cylindrical grinding wheels of different sizes are situated on one turret that is itself arranged on a displaceable slide. By pivoting the turret 180°, the two grinding wheels can be selectively brought up against different regions of a rotationally symmetrical workpiece. The workpiece is arranged in a workpiece receiver that is itself displaceable in the longitudinal direction of the workpiece. For grinding, the workpiece is ~~caused to rotate~~ rotated. In addition, in this known workpiece machine the workpiece receiver can be adjusted about an angle of +/-30° inclined to the displacement direction of the workpiece receiver. EP 1 022 091 A2 does not explain how grinding should proceed when the workpiece receiver is in an angled position. However, since pivoting of the turret carrying

the grinding wheel is expressly indicated in increments of 90°, it is obvious that with this known tool machine, as well, longitudinal grinding with one grinding wheel is intended when conical exterior contours with significant angles of inclination in the cone are to be ground.

Summary of the Invention

In contrast to this, the object of the invention is to provide a method and apparatus of the type cited initially in the foregoing with which the processing time can be decreased and a better grinding result can still be obtained.

~~The same object applies correspondingly for the apparatus claimed in claim 7.~~

This object is attained ~~in accordance with the method steps listed in the characterizing portion of claim 1 in that first~~ by having the active surface on the machine part held on one side at its exterior circumference [[is]] and ground, [[the]] a rotating circumferential contour of the [[first]] a cylindrical grinding wheel being positioned perpendicularly against the active surface, the machine part being displaced in the direction of its rotational and longitudinal axis relative to the first grinding wheel, whereby the axial extension of the first grinding wheel covers the radial angled extension of the active surface, and in that then, in the same clamping, the interior wall of the longitudinal bore is ground~~, a~~. A second grinding wheel of smaller diameter [[being]] is introduced into the longitudinal bore of the machine part by pivoting a grinding headstock, which carries at least the first and the second grinding wheel, and positioned radially against the interior wall.

Thus in the ~~inventive~~ method the machine part to be ground remains in a single clamping slate in which all of the grinding procedures are undertaken. This is made possible in that first, a first cylindrical grinding wheel is placed perpendicularly against the active surface and then a second cylindrical grinding wheel of smaller diameter is inserted into [[the]] a longitudinal bore of the machine part and placed radially against [[the]] an interior wall. The options for using two different grinding wheels on different processing surfaces of one and the same workpiece are known in general to one skilled in the art.

One special feature with the ~~inventive solution~~ present invention is that the first grinding wheel is placed perpendicularly at [[its]] a rotating circumferential surface thereof against the active surface that runs on an incline, whereby [[the]] axial extension or [[the]] width of the first grinding wheel covers the radial angular extension of the active surface. Thus, the active surface is ground with [[the]] a cylindrical circumferential surface of the grinding wheel using the vertical grinding method, whereby positioning is effected by mutual relative displacement.

A uniform cutting speed across the entire width of the grinding wheel results as an advantage. This ensures improved surface quality and surface structure. In addition, optimized dressing parameters are obtained when dressing the grinding wheel because when dressing the same parameters, namely, identical dressing speed, is attained as when grinding, as are the same revolutions per minute and advance values. Because the cutting speed of the grinding wheel remains the same across the active surface, the attainable surface roughness also remains the same. Optimum values for cutting volume per unit of time can also be

attained using the same cutting speed of the grinding wheel across the entire conical surface.

This is not the case for angular infeed grinding. Given an exterior diameter of the conical active surface, if one assumes a value of for instance 190 mm and an adjacent mean diameter (in the region of the longitudinal bore) on the active surface of 40 mm, the workpiece speed changes by a factor of 4.75 because of the rotation of the workpiece during grinding. The height of the conical surface is thus approx. 75 mm.

Given an assumed diameter of the corundum grinding wheel of 750 mm, the cutting speed at the exterior diameter of the conical surface is then approx. 80% of the cutting speed of the grinding wheel at the smallest diameter of the conical surface. This opposes the cutting volume, because it is highest at the greatest diameter on the conical surface. This means that because of the grinding wheel being placed perpendicular to the conical surface, the ratio of cutting speed to cutting volume that has to be carried across the conical surface is substantially improved.

Furthermore, significantly improved conditions when cooling the grinding zone result because practically these same conditions occur when grinding the active surface as during vertical grinding, so that there is a uniformly narrow cooling zone to which it is easy to feed the coolant/lubricant and which it also exits rapidly as well.

Overall, such advantages result that the ~~inventive~~ grinding method can be best performed

with ceramic bound CBN grinding wheels. Overall there is clearly a reduced number of cycles on modern processing machines with simultaneously substantially improved grinding results.

Fundamentally it would be possible for the first grinding wheel to be placed against the active surface of the machine part to be ground in the strictly radial direction in that the first grinding wheel is moved transverse to its longitudinal extension and in the angled direction to the machine part. In this case the machine part would have to be arranged at a position of the associated machine bed that remains the same. However, the apparatus required for performing the method is simpler when in accordance with the inventive method positioning occurs in that the machine part is displaced in the direction of its rotational and longitudinal axis relative to the first grinding wheel. From this movement, only an angled component falls on the grinding site on the active surface, but ~~it [angled component]~~ component deviates by only a small amount from the direction of the longitudinal axis so that there is nearly still vertical grinding in the conventional sense. A lower force component results in the radial direction of the active surface so that the running surface can be worked with optimized advancing during grinding. This also reduces the grinding time, and improved accuracies in the grinding condition of the active surface still result.

The subsequent interior grinding of the longitudinal bore can be undertaken using longitudinal grinding. The procedure for ~~rough-grinding~~ peel-grinding, in which grinding is performed directly to the final diameter, also comes into consideration. However, it is also possible for the interior wall of the longitudinal bore to be ground using ~~angular~~ infeed grinding.

The latter method is particularly considered when in accordance with another advantageous method variant individual axial segments of the interior wall of the longitudinal bore are ground.

In a further design of the ~~inventive~~ method of the present invention, at least three grinding wheels are provided that are brought into their working position by pivoting three grinding spindles that carry the grinding wheels. Additional grinding procedures can be performed using the method expanded in this manner, or for instance interior cylindrical grinding can also occur in the conventional steps of pregrinding and finish grinding.

Finally, it is not mandatory to follow the sequence in which first the active surface of the machine part and then the interior wall of the longitudinal bore is ground. Fundamentally the reverse sequence is also possible. One skilled in the art of grinding will establish the sequence of procedures depending on the design of the machine part, because the amount of heating during grinding and the type of clamping are important.

~~In accordance with claim 7, the~~ The invention also relates to an apparatus for grinding a rotationally symmetrical machine part of the type cited in the foregoing in connection with the method. In an apparatus for grinding a rotationally symmetrical machine part provided with a longitudinal bore, [[the]] one end-face surface of which is embodied as an active surface in the form of a flat truncated cone with a cross-section with a straight contour, in particular for performing the method in accordance with ~~any of claims 1 through 6,~~ the above recited method there is provided:

~~—with~~ a clamping device for one-sided clamping of the machine part at its exterior circumference and for rotationally driving it,

~~—with~~ a grinding spindle slide that can be moved in a direction running transverse to the rotational and longitudinal axis of the machine part,

~~—with~~ a device for longitudinal displacement of the machine part in the direction of its rotational and longitudinal axis,

~~—with~~ a grinding headstock that is attached to the grinding spindle slide via a pivot axis running perpendicular to the displacement plane of the grinding spindle slide and that carries at least two grinding spindles that can be pivoted into the working position,

~~—with~~ a first cylindrical grinding wheel, arranged on the first grinding spindle and driven thereby, that is for vertical grinding of the active surface situated on the machine part and that has an axial extension that is larger than the radial angled extension of the active surface,

~~—~~and [[with]] a second cylindrical grinding wheel, arranged on the second grinding spindle and driven thereby, that has a smaller diameter than the first grinding wheel and that is for interior cylindrical grinding of the longitudinal bore of the machine part,

~~—~~whereby, depending on the pivot position of the grinding headstock, either the rotating circumferential surface of the first grinding wheel is placed on the active surface of the machine part to be ground or the

axis of the second grinding wheel runs spaced from and parallel to the rotational and longitudinal axis of the machine part.

~~If when this~~ When the apparatus is operated according to the method described in the foregoing ~~is used~~, first the grinding spindle slide is moved in the correct manner to the clamped machine part and the grinding headstock is rotated such that the first grinding spindle, at the cylindrical circumferential surface of the first grinding wheel affixed on it, is placed against the active surface of the machine part. The first grinding spindle must assume an angled position relative to the rotational and longitudinal axis of the machine part that is less than 90°. Then the active surface can be ground by the first grinding wheel using the vertical grinding method, that is, with its known advantages. Subsequently the grinding spindle slide is moved somewhat outward transverse to the rotational and longitudinal axis of the machine part and the grinding headstock situated on the grinding spindle slide is rotated about its pivot axis until the rotational axis of the second grinding spindle with the associated second grinding wheel is approximately in the rotational and longitudinal axis of the machine part. The second grinding wheel is then inserted into the longitudinal bore of the machine part and positioned radially so that interior cylindrical grinding of the longitudinal bore is performed. In this manner all necessary grinding procedures on the machine part are accomplished in one single clamping. However, the prerequisite in every case is a first grinding wheel, the axial extension or width of which is greater than the angled extension of the active surface, because otherwise the vertical grinding method of the active surface, with all its advantages, cannot occur.

One constructive advantageous further development of the inventive apparatus is that in the arrangement of two grinding spindles on the grinding headstock their axes run parallel to one another and the two grinding wheels are attached on the same side of the grinding headstock. In this manner it is possible to change between the two processing procedures with only minor displacement and pivot paths of the grinding headstock.

If additional grinding procedures are to be performed or if one of the individual procedures is to be performed in a plurality of steps, it can be advantageous when, in accordance with another embodiment three grinding spindles, each with a grinding wheel, are attached to the grinding headstock at angle intervals of 120° each. Then one of the three grinding spindles is selectively brought into the working position.

Advantageously, the clamping device is a chuck with centrally adjustable clamping jaws and that can also be driven to rotate. Such chucks have proved to be reliable and are known.

In accordance with one additional embodiment, it is advantageous when the clamping device is located on a grinding table that can be moved in the rotational and longitudinal axis of the machine part relative to the grinding spindle slide. The positioning movement when grinding the active surface is then performed in that the grinding table, with the machine part, is moved in the longitudinal direction of the machine part relative to the first grinding wheel.

Brief Description of the Drawings

The invention will be described in greater detail in an exemplary embodiment using the figures. ~~The figures are as follows:~~

Figure 1 is a view from above onto an inventive apparatus in a first processing phase;

Figure 2 depicts a view corresponding to that in Figure 1 in the subsequent processing phase;

Figure 3 is a section of the machine part to be ground;

Figure 4 explains how the inventive method is performed in the first processing phase; and

Figure 5 is the depiction corresponding to that in Figure 4 of the second processing phase.

Description of the Preferred Embodiments

Figure 1 first provides a schematic illustration of ~~the inventive~~ an apparatus with which ~~the inventive~~ a method for grinding can be performed. A top view of an apparatus for grinding the machine part is shown. Situated on a machine bed 1 is a workpiece headstock 2. It is provided with a chuck 3 that is driven to rotate and on which are situated four clamping jaws 4 that are centrally

controlled. The machine part to be ground, labeled 5, will be described greater detail below.

The workpiece headstock 2 has a longitudinal axis 6 that is also the rotational axis of the chuck 3. When the machine part 5 is clamped in the chuck 3, the rotational and longitudinal axes of the workpiece headstock and the machine part 5 coincide.

In the exemplary embodiment illustrated, the workpiece headstock 2 is affixed to a grinding table 7. Together with the workpiece headstock 2, the grinding table 7 is moved in the direction of the longitudinal axis 6, which is also the conventional Z-axis in the context of a CNC control.

Furthermore situated on the machine bed 1 is a grinding spindle slide 9 that can be moved by means of a displacement motor 8 in a direction transverse to the longitudinal axis 6 of the workpiece headstock 2. On the grinding spindle slide 9, a grinding headstock 10 is pivotably arranged about a pivot axis 11. The direction of pivot is indicated by the rotating arrow B. The pivot axis 11 is perpendicular to the grinding spindle slide 9 and will normally run vertically.

A first grinding spindle 12 and a second grinding spindle 13 are situated on the grinding headstock 10. The rotational and drive axes of the two grinding spindles are parallel. A first grinding wheel 14 is affixed to the grinding spindle 12. The grinding spindle 13 is fitted with a second grinding wheel 16 that is affixed to a grinding arbor 15. As Figure 1 clearly indicates, the first grinding wheel 14 and the second grinding wheel 16 are both arranged on the same side of the grinding headstock 10.

Figure 1 illustrates the first processing phase of the grinding procedure in which the circumferential surface of the first grinding wheel 14 is placed against the active surface of the machine part 5 to be ground.

~~In contrast,~~ Figure 2 provides ~~the same~~ a view~~, but~~ of the second processing phase in which the axis of the second grinding wheel 16 runs spaced from and parallel to the longitudinal axis 6 of the workpiece headstock 2.

In order to move from the position in accordance with Figure 1 to the position in accordance with Figure 2, first the grinding spindle slide 9 must be moved somewhat outward in the direction of the X-axis, that is, transverse to the direction of the longitudinal axis 6. Then the grinding headstock 10 on the grinding spindle slide 9 can be pivoted about an angle of somewhat more than 90°, whereupon the second grinding spindle 13 with the second grinding wheel 16 assumes the position visible in Figure 2. The pivoting movement is also illustrated by the rotating arrow B in Figure 2.

Figure 3 is an enlarged section of the machine part 5 to be ground. The machine part is rotationally symmetrical to the rotational and longitudinal axis 17. It comprises a hub part 18 and a coned flange 19 and a longitudinal bore 20 passes through its entire length.

The longitudinal bore can be graduated so that it is not necessary to grind its entire length. In general it is sufficient when the longitudinal bore is ground on the axial segments 21, 22, and 23. At its large end-face surface, the coned flange 19 is embodied like a flat truncated cone with a cross-section that has a straight contour.

The machine part illustrated is a conical disk in a continuously variable gear; in its assembled condition, a chain, belt, or the like slides on the active surface 24. Two active surfaces 24 oppose one another; by changing the distance between them, the radius on which the chain or belt slides can be changed, this resulting in different transmission ratios. Thus it is clear how important the entire and careful grinding of the active surface 24 is for the functioning of the finished continuously variable gear.

The machine part illustrated in Figure 3 has a cylindrical clamping surface 25 and a planar stop surface 26 that are for clamping in the aforesaid chuck 3. The clamping jaws 4 enclose the cylindrical clamping surface 25, while the axial stop is provided by the stop surface 26 on the clamping jaws 4. The machine part 5 is thus clamped exteriorly on one side so that the entire end face, which is on the right-hand side in Figure 3, and in particular the active surface 24 are free for processing. In addition, a small grinding wheel can be inserted into the longitudinal bore 20 for the purpose of interior grinding.

Figure 4 illustrates the first processing phase in which the active surface 24 of the machine part 5 is ground using vertical grinding.

As stated in the foregoing, first the machine part 5 is clamped between the clamping jaws 4 of the chuck 3. The workpiece spindle is then driven to rotate, as a rule by a variable-speed electromotor. With this, the machine part 5 rotates about its rotational and longitudinal axis 17, which is identical to the longitudinal axis 6 of the workpiece headstock 2.

The first grinding spindle 12 with the first grinding wheel 14 is already in the position described using Figure 1. In that the machine table 7 with the workpiece headstock 2 is now displaced to the right in the direction of the Z-axis in Figure 4, the rotating first grinding wheel is positioned against the active surface 24 of the machine part 5. The axial extension 28 of the second grinding wheel 14 is somewhat larger than the radial angled extension of the machine part 5. Thus the entire active surface 24 is ground by the first grinding wheel 14 using the vertical grinding method with the advantages described in the foregoing.

The first grinding wheel 14 is a ceramic bound CBN wheel that provides a long tool life.

Figure 5 depicts the second processing phase, which corresponds to the view in accordance with Figure 2. In the illustration in accordance with Figure 5, the second grinding wheel 16 has already been inserted into the longitudinal bore 20 and is processing the axial segment 21 of the longitudinal bore 20. The rotational axis of the second grinding wheel 16 is situated spaced from and parallel to the common longitudinal axis 6 of the workpiece headstock 2 and machine part 5. In this phase interior grinding of the segments 21, 22, and 23 of the longitudinal bore 20 is performed, whereby this cylindrical grinding can occur as longitudinal grinding, rough-grinding, or angular infeed grinding.

Abstract

~~Disclosed is a~~ A machine part [[5]] with a conical effective surface, which is machined by means of a device comprising a machine bed [[1]], a longitudinally movable grinding bench [[7]], and a workpiece spindle head [[2]] that clamps the machine part [[5]] by means of clamping jaws [[4]] via a chuck [[3]]. The conical effective surface of the machine part [[5]] is ground by means of a first grinding disk [[14]] in a vertical grinding mode by longitudinally moving the grinding bench [[7]] in the direction of the longitudinal axis [[6]]. The associated grinding spindle head [[10]] is provided with a first grinding spindle [[12]] for the first grinding disk [[14]] and a second grinding spindle [[13]] for a second grinding disk [[16]] that is fixed to a grinding arbor [[15]]. The grinding spindle head [[10]] is fixed to a grinding spindle carriage [[9]] so as to be pivotable around a vertical shaft [[11]], ~~said~~ the grinding spindle carriage [[9]] being movable in the direction of the x-axis via a displacement motor [[8]]. ~~B indicates the swiveling direction of the grinding spindle head [[10]] while X and Z represent the common axes referred to in CNC technology.~~ The first grinding disk [[14]] can be driven out of the area of the machine part while the second grinding disk [[16]] can be made to act upon the machine part [[5]] in order to internally grind a longitudinal borehole.